FACT Foundation

Dual Fuel technology: Combined use of Jatropha oil and biogas in a diesel engine

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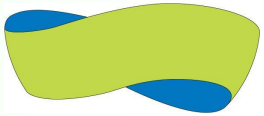
May 15 - 2008

Overview



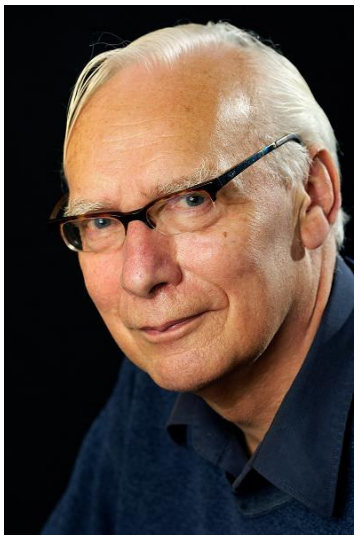
- FACT Foundation
- Jatropha Rural Electrification
- Jatropha Biogas Potential
  - Energy Balance
- Dual Fuel Technology
  - Technological aspects
  - Experimental results
- Practical Application
- Conclusions
- Discussion / Questions

FACT Foundation

- **F**uels from **A**griculture in **C**ommunal **T**echnology

- Knowledge Centre
- Projects
- Research

- Mission: **production, use and commercialisation of biofuels for local development**



FACT Network

- FACT Associates
- Research Partners
  - Wageningen University
  - University Eindhoven
- Linked research
  - University Groningen
  - University Utrecht
  - University Leuven
- 1000+ members

FACT Themes

1. **Agriculture:** Bio-energy production systems

2. **Conversion:** Biomass to energy carriers (gaseous/ liquid/ solid)

3. **End use:** Diesel engines, Biogas, Electricity supply

FACT Projects

- Mali
- Mozambique
- Honduras

Rural Electrification

Mali Specifications

- 3 Deutz Diesel Engine (shipping engine)
- 3 x 100 kW generators
- Fuel Consumption
  - 40 kW
  - Jatropha oil: 12 liter/hr
- Aim
  - Electricity 24 hours/day
  - 365 days/ year

Biogas Production (1)

- Jatropha yield
  - 1000 kg seeds/ ha/yr
  - 3000 kg of fresh fruit shells/ha/yr

  - 200 kg oil = 250 liter
  - 800 kg presscake

Biogas Production (2)

- Biogas Yield (1 MT/seeds)

- Presscake / oil residue
  - 800 kg → 360 m3 biogas
- Fruit Shells (fresh)
  - 3 ton → 100 m3 biogas

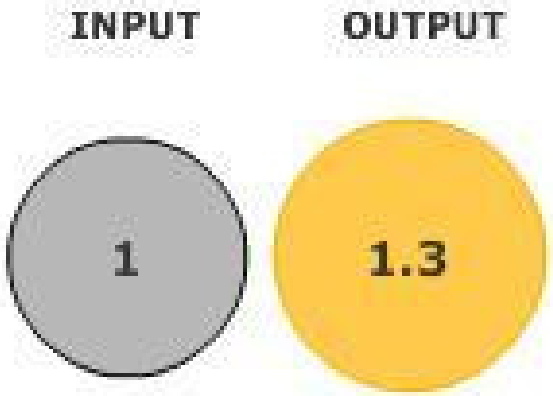
- Electricity (totals)
  - Oil: 833 kWh
  - Presscake: 720 kWh
  - Fruit shells: 200 kWh

Energy Balance

NATIONAL GEOGRAPHIC

Energy Balance

Fossil-fuel energy used to make the fuel (input) compared with the energy in the fuel (output)



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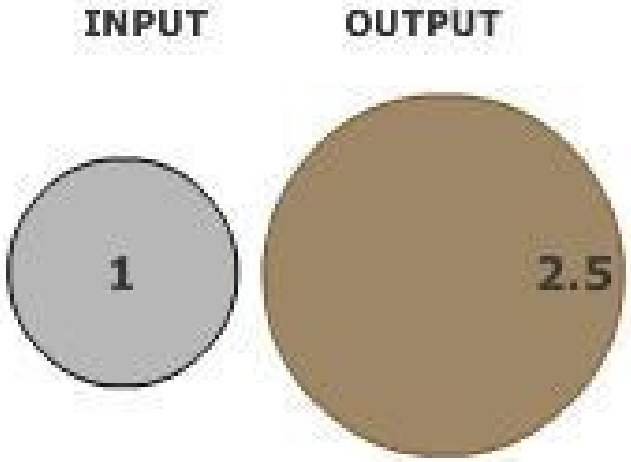

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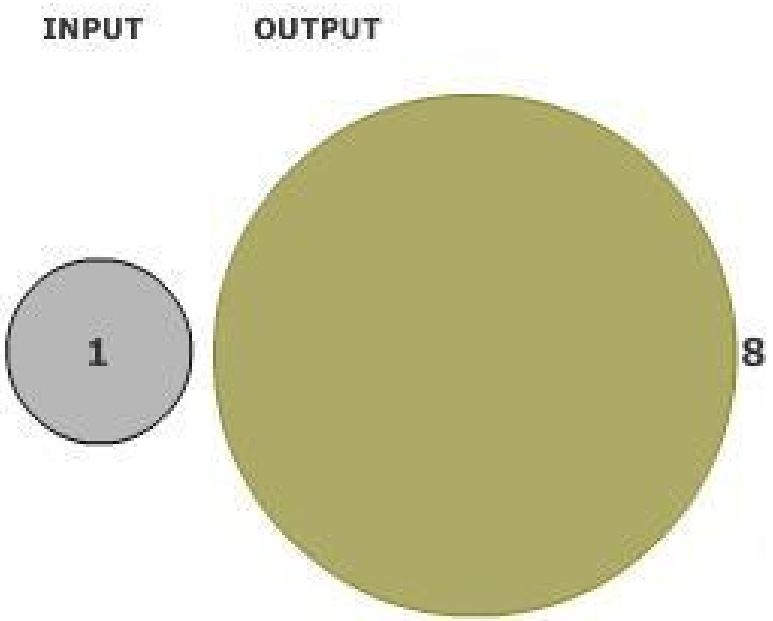

Energy Balance

Pure Plant Oil

Energy Balance

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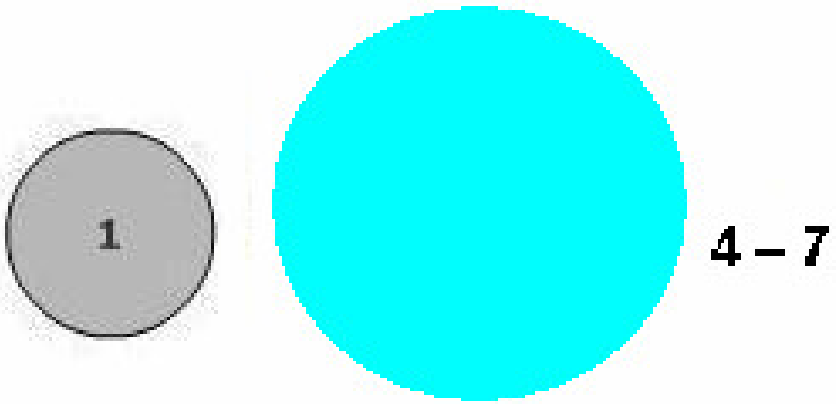
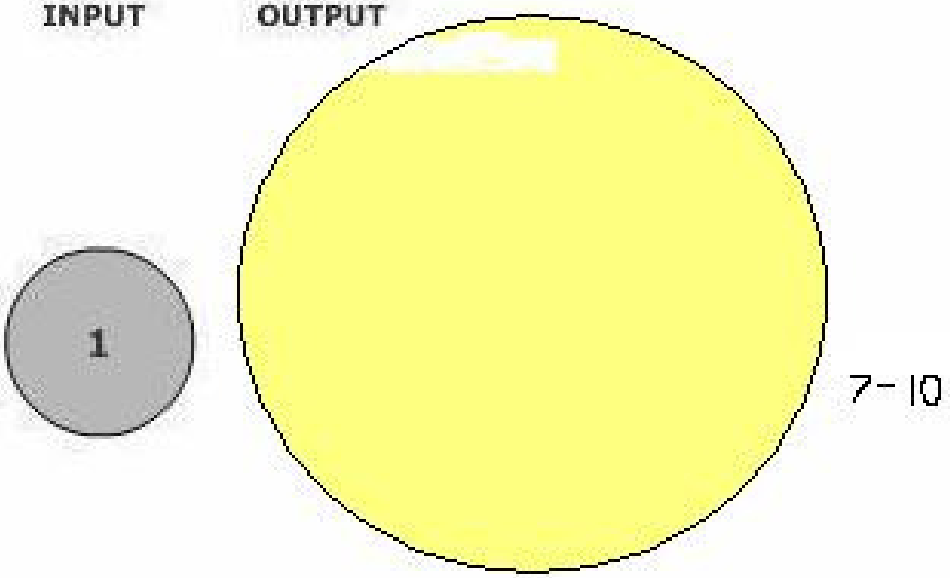


Energy Balance

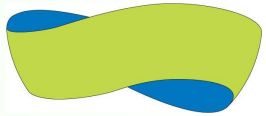
Jatropha PPO + Biogas

Energy Balance

Fossil-fuel energy used to make the fuel (input) compared with the energy in the fuel (output)

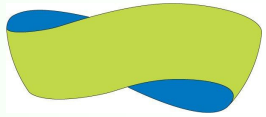


Dual Fuel Technology



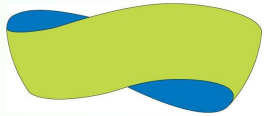
- Historical overview of Studies on Compressed Ignition (CI) engines
  - Focus on mixing diesel with biogas/ producer gas (LPG, NG, CNG, Methane, Propane)/ hydrogen
  - Use of Pure Plant Oil as Fuel
  - Studies going back even before 1980 for mixed use

Dual Fuel Technology



- New Experiment
  - CI Diesel Engine running on PPO mixed with biogas
  - Performed at request of FACT at the Technical University of Eindhoven by Evie Kerkhof (student)

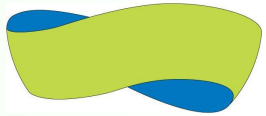
Dual Fuel Technology



- Research Question:

  What is the effect of running a 1 cylinder diesel generator set on dual fuel mode with Jatropha oil and biogas on engine performance and what are the limiting factors and boundaries?

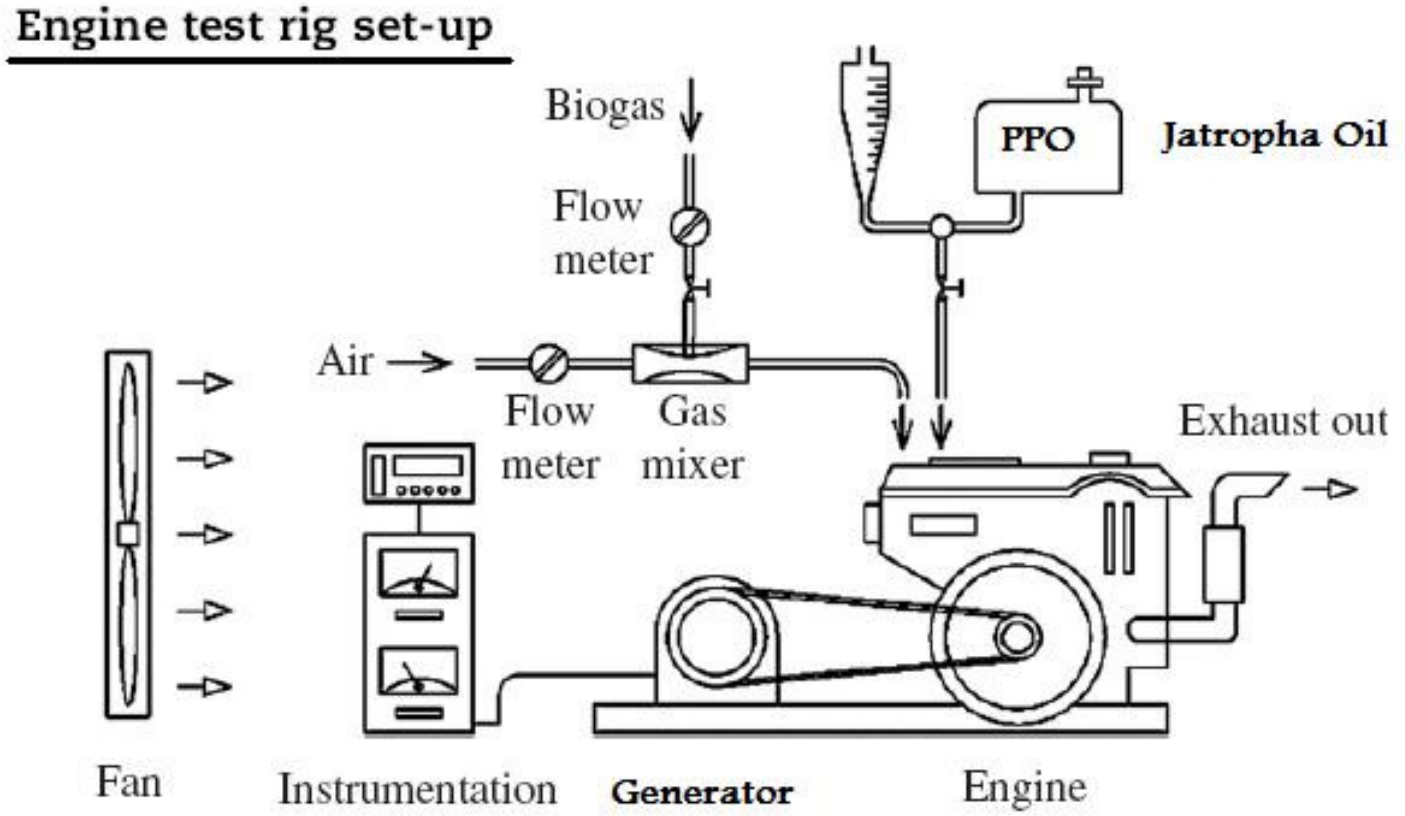
Dual Fuel Technology



Experimental Set-Up

- 12 kW 1 cylinder converted diesel engine
- Load: 12 - 13 kW (6 heaters)
- Fuels:
  - 100% methane
  - Simulated biogas
  - Jatropha oil
- Gas pressure reduction valves
- Gas mixer (Venturi)
- Measuring equipment

Dual Fuel Technology



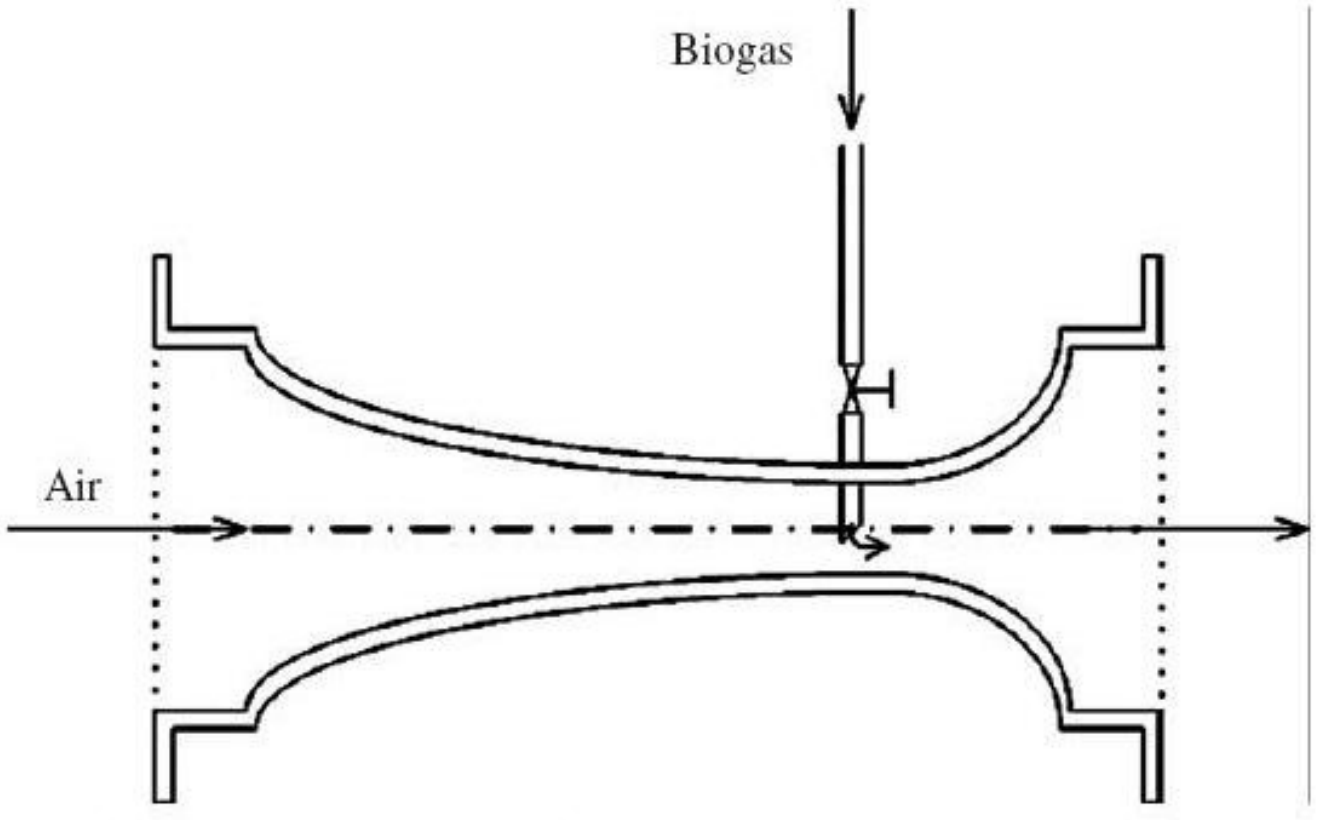
Picture taken and adapted from Tippayawong N, et al. (2007)

Dual Fuel Technology

Dual Fuel Technology

Dual Fuel Technology

Biogas — inlet air mixing device



from: Tippayawong N, et al. (2007)

Dual Fuel Technology

Dual Fuel Technology

Dual Fuel Technology

- Three important ratio's
  - Fraction of methane in biogas

$$\sigma = \frac{m_{CH4}}{m_b} \qquad \alpha = \frac{n_{CH4}}{n_{CH4} + n_{CO2}}$$

  - Fraction of oil in total fuel

$$\theta = \frac{m_{oil}}{m_{oil} + m_b} \qquad \beta = \frac{n_{oil}}{n_{oil} + n_b}$$

  - Fraction of air in the intake mixture

$$\xi = \frac{m_{air}}{m_{air} + m_b} \qquad \psi = \frac{n_{air}}{n_{air} + n_b}$$

Dual Fuel Technology

- Theory

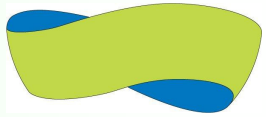
Overall molar reaction equations dual fuel mode

$$CH_4 + \left(\frac{1}{\alpha} - 1\right) CO_2 + \frac{\beta}{\alpha(1-\beta)} C_{56}H_{101}O_6 + \lambda \cdot \left(78.25 \cdot \left(\frac{\beta}{\alpha(1-\beta)}\right) + 2\right) O_2 + 3.76 \cdot \lambda \cdot \left(78.25 \cdot \left(\frac{\beta}{\alpha(1-\beta)}\right) + 2\right) N_2 \rightarrow$$

$$\left(\frac{1}{\alpha} + 56\left(\frac{\beta}{\alpha(1-\beta)}\right)\right) CO_2 + \left(2 + 50.5 \cdot \frac{\beta}{\alpha(1-\beta)}\right) H_2O + 3.76 \cdot \lambda \cdot \left(78.25 \cdot \left(\frac{\beta}{\alpha(1-\beta)}\right) + 2\right) N_2 + (\lambda - 1)\left(78.25 \cdot \left(\frac{\beta}{\alpha(1-\beta)}\right) + 2\right) O_2$$

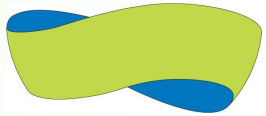
- Performance parameters
  - Thermal efficiency
  - Volumetric efficiency
  - Relative Air Fuel Ratio

Dual Fuel Technology



- Technical aspects
  - Higher combustion temperatures → other lubrication oils needed
  - Oxygen supply for Combustion

Dual Fuel Technology

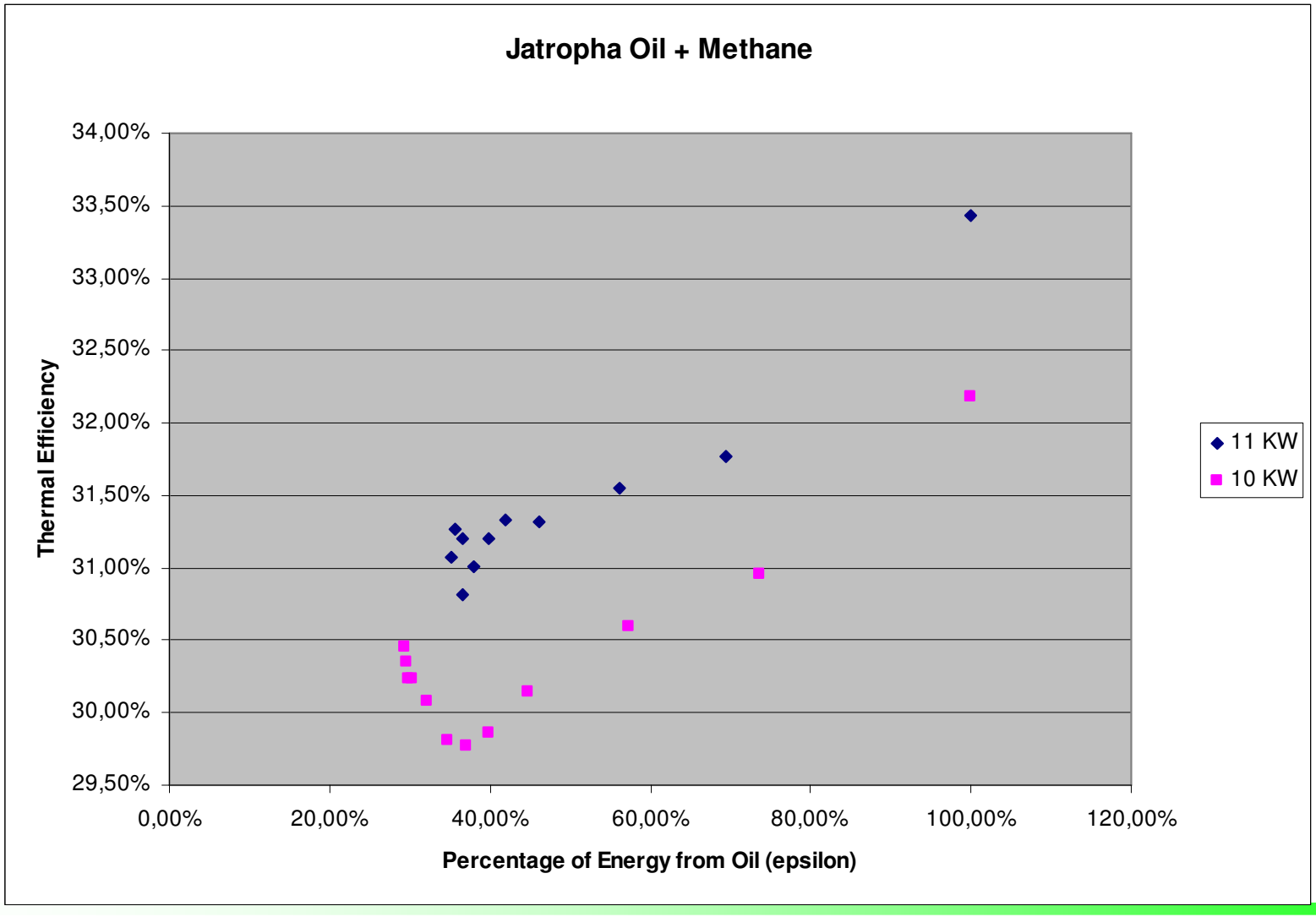


- Preliminary results
  - PPO consumption is reduced up to 75% while running on biogas
  - Maximally 80% of the energy is coming from methane
  - Higher thermal efficiency at higher loads
  - Slight decrease in thermal efficiency w/ more gas
  - Methane input maximally 0,72 liter/second
  - Slight increase in power output
  - Smoother operation up to 55% mixing of gas

Dual Fuel Technology

% replacement oil	η therm(%)	Poutput(kW)
0,00%	33,43%	11,13
26,13%	31,77%	11,24
39,88%	31,55%	11,27
50,00%	31,32%	11,30
54,62%	31,33%	11,31
56,66%	31,20%	11,32
58,34%	31,01%	11,32
60,11%	31,21%	11,32
61,21%	31,26%	11,32
59,77%	30,82%	11,32
61,46%	31,07%	11,30

Dual Fuel Technology



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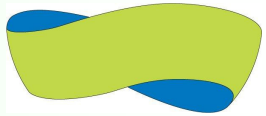
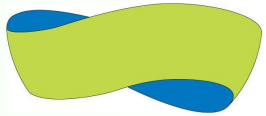


- Future Research
  - Long duration tests
  - Pressure release data (in cylinder)
  - Measure engine temperature
  - Effects of polluted biogas (H_2S) → forms acids that cause corrosion
  - Comparison with gas engines
  - Better regulation of gas-input
  - Exhaust fumes (NOx – HC's – Particulates)

Practical Application

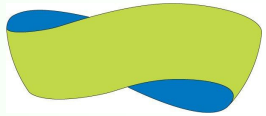
- Risks
  - Gas transport/ storage/
  - Risks related to use
  - Backfiring
- Obstacles
  - Gas infrastructure
  - Technological requirements (biogas production and cleaning – engine adaptation)

Practical Application



- Advantages of biogas as dual fuel
  - Local energy production + oil for sales
  - Security of energy supply (alternate source)
  - Simple production of biogas
  - Possibility of switching back to Pure Plant Oil (PPO) or Diesel
  - Flexible mixing depending on fuel supply

Conclusions



1. Dual Fuel operation of a Diesel engine on Biogas + Jatropha Oil is possible

2. Could double Jatropha energy output per hectare / extra oil available for market

3. Development of commercially available engine technology is necessary

END – thank you!

- Questions?
- Preguntas?